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ABSTRACT

A brief overview of computer-assisted instruction (CAI) is provided. The history and theoretical framework of CAI and typical developmental stages involved in the implementation of a CAI system are outlined. The way CAI determines background knowledge of a student, presents information necessary to learn new concepts, sets its pace according to student needs, reinforces previous learning, and evaluates student performance qualifies it as an expert system. Developmental stages covered include: (1) conceptualization (development of project rationale); (2) design (development of behavioral objectives, choice of a learning theory, selection of content and instructional models, development of means of sequencing instruction and presenting materials, student support requirements, measurement of student performance, selection of computer language/program, development of means of selecting an "authoring system," and validation of design); and (3) implementation (coding in suitable author language, testing of the system to determine whether it meets product specifications, determination of overall instructional value of the CAI system, and marketing). Advantages and unresolved issues related to CAI are discussed. (TJH)

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THE DEVELOPMENT OF CAI: AN EXPERT SYSTEM IN EDUCATION

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THE DEVELOPMENT OF CAI: AN EXPERT SYSTEM IN EDUCATION

Computer Assisted Instruction (CAI) simulates the classroom behavior of an experienced teacher just like DENDRAL determines chemical structure and MYCIN helps physicians to diagnose infections (Winston, 1977). Although CAI meets the anology of expert systems used in the field of artificial intelligence, it is not yet regarded as a true expert system. The reason for this discrepancy is more the quality of the CAI courseware than it is the characteristics of CAI. The way CAI determines background knowledge of a student, presents information necessary to learn new concepts, sets its pace according to student needs, reinforces previous learning, and evaluates the performance, truly qualifies it to be an expert system. Like other expert systems, a data base may be used with CAI to make it a knowledge-based system.

The presentation of material in the classroom in such a way as to make students learn and understand is a very difficult task and has always been a great challenge for teachers. Besides, learning is a complex process and is unique to each individual. Therefore, teaching students according to their abilities and pace is a difficult if not impossible task for a classroom teacher to accomplish in a short, fixed classroom session. The advent of computer technology and the development of CAI

courseware has not only made individualized instruction possible but has also eased the pressure on classroom teachers.

Computer assisted instruction may be viewed in two ways depending on the purpose for which it is used. The first is as a supplement to regular classroom learning. This purpose is called adjunct CAI (Kearsley, 1977). Most of the CAI courseware available on the market is used for this purpose. The second is as a substitute for the teacher and it is called primary CAI. The duration of such CAI sessions is large and they are usually independent. They are best used for independent study and distance learning. Other terminology used in the field includes distinction between computer assisted instruction and computer assisted learning (CAL). The former stresses objectives and the measurement of results while the latter is more concerned with the achievement of goals (Godfrey & Sterling, 1982).

History

CAI is an idea of the late 50's. The major contributors to the field include the United States, Great Britain, Canada, and Japan. Most of the work, however, was completed in the United States and Great Britain. Recently a large number of European and third world countries have become interested in CAI and they are either developing their own courseware

or using programs that are developed by leading institutions in the United States and Britain (Neil, 1978).

A major breakthrough in CAI occurred in the United States and Britain simultaneously. In 1972, the British government funded a five year CAI project called National Development Program in Computer Assisted Learning (NDPCAL) at the University of Leeds (Hooper, 1978). At about the same time, the National Science Foundation in the United States funded the establishment of a consortium called CONDUIT consisting of the Universities of Oregon, North Carolina, Iowa, Texas, and Dartmouth. The purpose of the consortium was to establish a national clearinghouse to acquire, evaluate, and distribute quality CAI courseware (Howe & Romiszowski, 1978). Another consortium called Minnesota Educational Computing Consortium resulted in the installation of hundreds of microcomputers in the State of Minnesota (MECC, 1979). Another project that was funded by the National Science Foundation and had significant bearing on the growth of CAI courseware was PLATO; it is housed at the University of Illinois. PLATO is the largest single project in the world and provides CAI courseware in a variety of disciplines through a network of mainframe, mini, and microcomputers to all the school systems in the State of Illinois.

Extensions of this project are housed at the University of Florida and Florida State University and include courseware in music education and remedial mathematics, respectively (Chambers & Sprecher, 1980).

In the field of primary CAI, the National Science Foundation funded a project called Time-Shared Interactive Computer Controlled Information Television (TICCIT) to provide undergraduate studies in English and mathematics (Morrison, 1980). It was developed at the University of Texas. In Britain primary CAI courseware has been developed and used by the Open University.

Development of CAI System

This section outlines the development of CAI courseware. The term CAI courseware and CAI system are used interchangeably in the following sections. This section is divided into three parts: (1) conceptual stage, (2) design stage, and (3) implementation stage. Each stage is discussed in detail in the following text.

Conceptual Stage

The conceptualization of a CAI system occurs either to meet a need or to be innovative. Sometimes, curiosity is another element to realize a CAI system. For example, to provide individualized instruction in mathematics is a need, while the use

of the computer in mathematics instruction is an innovation. Similarly, to determine the efficiency of teaching mathematics by use of a computer over the traditional method demonstrates the curiosity. The CAI system may, therefore, be considered goal-oriented, while need, innovation, and curiosity determine goals.

Every goal realized refers to a group of people to whom it is applicable. In the above example, the goal of teaching mathematics by use of a computer must define the group to whom such instruction must be imparted. This group may be pre-school children, high school students, college graduates, or just neighborhood adults. The identification of goals and groups to whom these goals appply must be clear. Any ambiguity may jeopardize the usefulness of the whole system. Additional information may be used to refine these goals. Factors like age, grade level, ethnic background, socio-economic status, or geographical limits may be used to mark the boundaries that distinctly separate the selected groups from the rest of the population.

A significant outcome of this stage is the development of project rationale. It requires considerable amount of mental activity. The resulting product must be complete and free of missing links. As soon as the need for the system is

established and the goals are realized, the task of bringing this conceptual model into reality begins.

Design Stage

This stage involves the development and selection of a variety of structures such as the development of objectives, choice of instructional model, and the selection of coding language so that their interface brings the proposed model into reality. This phase of CAI system development is very crucial because each structure in the system should meet the specifications of the system realized at the conceptual stage, must match the project rationale, and satisfy the output requirements. The successful completion of this stage involves the accomplishment of the following tasks.

Development of Objectives:

In order to develop objectives, a distinction between goals and objectives is necessary. Goal refers to a broad outcome while objective is a single independent component that meets part of the goal. Therefore, a goal may be realized by achieving a set of objectives. When developing objectives, care should be taken that they are mutually exclusive, clear, concise, and related to the goal. In an example given earlier, the goal of teaching mathematics to elementary school children involves proficiency in doing addition sums which requires (1) recognition of numbers, (2) mastery in counting, and

(3) knowledge of addition rules. Therefore, proficiency in number recognition, proficiency in counting, and proficiency in addition rules are the objectives that together make it possible to attain the goal of having proficiency in doing addition sums. All goals of the conceptualized system must be translated into sets of objectives for their implementation. A detailed discussion about the development of objectives is available in Gronlund (1985).

Development of Behavioral Objectives:

The objectives developed in the preceding section are generally too broad and are further divided into several sub-tasks such that the achievement of these sub-tasks results in the achievement of an objective. The sub-tasks, sometimes referred to as rules (Godfrey et. al., 1982), may be called specific objectives. A specific objective is written in behavioral terms so that it could be measured. For this reason, specific objectives are also called behavioral objectives.

The development of objectives and behavioral objectives from a given set of goals is a mental exercise and needs skill and creativity. The validity of the CAI system depends completely upon how these objectives are written and what do they try to accomplish.

One of the objectives for a given goal, in the example of teaching mathematics discussed earlier, was knowledge of addition rules to add numbers. This objective, for example, may have the following behavioral objectives: (1) Ability to add two single digit numbers correctly 90% of the time, (2) Ability to add more than two single digit numbers correctly 90% of the time, and (3) Ability to add two double digit numbers with carry 90% of the time, etc. A complete discussion about developing behavioral objectives is given in Gay (1985).

Learning Theory:

Learning theory provides a theoretical framework from which to develop CAI systems. The choice of a particular theory determines the strategy to be used to accomplish the goals of the system. It dictates the mode of presenting the information, step size (the smallest piece of information), the difficulty level of the content, the means to reinforce correct responses and to extinct wrong answers. A brief account of learning theories is given below.

Classical Conditioning. According to this theory, learning takes place as a result of association between a stimulus and the response. Therefore, a stimulus is associated with the response and after a reasonable practice, an unconditioned stimulus starts eliciting a conditioned response that was formerly elicited with conditioned stimulus. The

theory was first introduced by Ivan Pavlov in 1927, and is more frequently used with animals (Wrightsman, Sigelman, & Sanfored, 1979). The work of Watson (1920 & 1928) shows how classical conditioning may be used in human learning.

Operant Conditioning. Operant conditioning stresses on rewarding the organism to reinforce elicited response and to increase the probability of similar future behavior (Skinner, 1951 & 1961). Unwanted responses are extincted by punishment that may be a withdrawal of reward, already given as reinforcement. This theory is very effective in behavior modification. Most of the CAI courseware available in the market is based on this theory. Unlike classicial conditioning, the response of the organism in operant conditioning mode is voluntary.

Cognition Theory. According to this theory, learning takes place due to the cognitive processes that occur inside the organism. The learner interacts with the environment, processes the information, and elicits the response. External reinforcement is not needed for this kind of learning. Moreover, in most of the learning situations, distributed practice brings better outcome than massed practice (Turner, 1983).

Social Learning Theory. Bandura (1962) and Bandura and Walters (1963) claim that learning may

take place by observation, imitation, or modeling, without immediate reinforcement for the elicited response. This theoretical framework is called social learning theory. Some psychologists view imitation as another form of operant conditioning in which intrinsic or extrinsic reward produces a generalized tendency for imitation.

Selection of Content:

After the goals are translated into objectives and specific objectives have been developed for quantitative measurement, the process of selecting content starts. The content is broadly identified by the goals. The selected content must be meaningful and should match intelligence, motivation, and learning styles of students. Factors like learners' age, previous knowledge, and retention level are also given due consideration in the selection of content. The content is divided into small manageable tasks related to a specific set of behavioral objectives and is called instructional unit. The size of the unit and the number of concepts to include in one unit depend on how hard the concepts are and the level of background knowledge of learners.

The services of an expert are needed to determine content validity as well as the effectiveness of the system to achieve the CAI objectives. Sometimes pilot studies are needed to determine content and construct validity of the selected

content before its use in the CAI system.

Instructional Model:

The instructional model controls the CAI system in the presentation of content to students. There are six commonly available strategies and each one is discussed below.

Drill. This strategy is based on classical theory of learning and assumes that a concept can be learned with a reasonable amount of practice. The emphasis is on practice and no effort is made to diagnose the source of a learner's errors. There are five ways to handle incorrect responses of learners (a) ignore the error and continue with the session, (b) repeat the question in an attempt to elicit the correct response, (c) try prompts, (d) provide remediation to correct the error made, or (e) accept error as incorrect and keep questioning till correct answer is given.

The best alternative, however, is to display the correct response whenever an incorrect response is given by the learner, acknowledge the correct response by some way of appreciation, and provide positive reinforcement to complete the unit. Drill is considered a good instructional strategy to memorize simple facts. However, it is not appropriate for complex concepts. Continuous use of this strategy creates boredom among students.

Tests. In this instructional mode, material is presented like a test item. Unlike drill strategy, no prompt is given when incorrect responses are made. This strategy sometimes is called learning through tests. The material under this strategy may be presented to learner by using a single or a combination of several formats such as (a) true-false choice, (b) multiple choice, (c) fill-in-the-blanks, and (d) short answers.

Some educators believe that teaching by tests is one of the ways to achieve instructional objectives. However it is not considered an appropriate strategy when the content is being presented to the learner for the first time. Most often, tests are used to evaluate student performance to determine mastery of content and retention.

Inquiry. According to this strategy, the student is provided with a database and a set of rules. The students generate questions themselves out of curiosity and by use of database and given rules, find answers to such questions. This instructional model is very useful when development of curiosity and creativity are one of the objectives. The implementation and update of database, however, is a time consuming activity and requires database management skills.

Simulation. Simulation was seldom used in the past but has become very common in recent years.

According to this mode of instruction, the test items and examples are provided to make learners guess, make assumptions, do intuitive thinking, and respond to questions. Simulation is exhaustive in determining the truth. It develops inductive thinking and helps the learner learn underlying rules. It is also very useful in determining end results of some dangerous experiments and expensive ventures before actually carrying them out. Simulation, however, has not proved successful with young children. Moreover, keeping track of student performance under simulation mode, is a difficult task.

Games. Games as a means of learning started a few years ago. Because of the low cost and accessibility of micro-computers, games have become very popular particularly among youngsters. Each game has a start-point, an end-point, and a set of rules to play by. Games are not considered good for students who would dislike competition for fear of losing. Games are usually made effective by the extensive use of graphics. The usefulness of games in classroom situations is, however, debated by Dennis (1979).

Tutorial. Tutorial is a mixture of teaching, practice, and evaluation modes. It has built-in diagnostic set-up that is triggered when the learner starts making errors. It has a very complex

branching system and provides different kinds of feedback. It usually includes re-displaying the data, offering immediate remediation, providing access to help, suggesting to quit, moving to another unit, or sometimes, asking a question in several ways. The present CAI courseware is rich in tutorial.

The implementation of tutorial is very complex because of its branching strategy. It needs a large memory space to implement branching and a sophisticated mechanism to recognize correct responses. It also needs a complex system to monitor student performance during and after the session. The usefulness of tutorial, however, overrides the implementation-level difficulties. It is very effective in teaching complex concepts and providing speeded learning, individualized pace, and equal opportunity to learn at all levels of the unit.

Sequence of Instructions:

Sequence of instructions, also called branching strategy or mapping, handles the sequence in which the instructional material is presented to the learner. It is the backbone of the CAI system and is very complex in nature.

Branching strategy is determined uniquely for each learner on branching junctions built-in into the unit. The path a student may take out of the several available options depends on the learners' responses

to the questions preceding that branching junction. These paths must be identified at the time the instructional unit is developed. The branching strategy customizes the unit according to the needs of the learner and must meet the standards of individualized instruction. One of the criteria that makes one CAI system better than the other is the number of optional paths built into the system at each branching junction and the way they are spread out throughout the instructional unit.

Presentation of Material:

The material presented to the learner falls into three main categories called teaching, practice, and testing. The smallest piece of information presented to the learner is called a frame. The frames, therefore, may be called teaching frames, practice frames, and testing frames. Though most of the frames fall into the categories specified above, they may also be categorized by function (Fry, 1963). The examples of such frames include:

Introduction Frame. It introduces new pieces of information.

Definition Frame. It provides specific definition of the concept under consideration.

Lead-In Frame. It prepares the student for new information.

Augmenting Frame. It gives new information to

the student but does not require correct response.

Specifying Frame. This frame exemplifies a general rule through specific examples.

Generalizing Frame. It points out the common characteristics of learned problems for generalization.

Distinguishing Frame. It requires the student to distinguish between concepts that can be confused.

Associative Frame. It creates the link between an already learned concept and the expected response.

Dove-Tailing Frame. It presents two or more ideas together and the learner is required to answer them separately.

Selection Frame. It is used to minimize the error rate.

Stimulus-Response Frame. In this frame, an item used as stimulus in one frame is used as a response in the following frame to strengthen the link between the two.

Vanishing Frame. It is the frame in which there is a graduate withdrawal of prompts.

Criterion Frame. It tests the learning of the material already presented.

Review Frame. It reviews the material already learner.

Student Support:

Providing student support during the CAI session is very important to simulate classroom situations. When the student is confused, frustrated, or is completely lost, a good CAI system should help the student the way a teacher would do in the classroom. It includes giving prompts, providing tutorial assistance, or even routing the student back to previous information to improve understanding. The student support component of the CAI system provides the following alternatives to the learner.

1. Provide for background information to help understand the material better.
2. Help in understanding the material and giving prompts to go through the course sequence successfully.
3. Provide diagnostic sequence to identify student problems. This is possible by keeping track of errors made by the learner and then analyzing the error types and error pattern to diagnose the source of errors.
4. Provide remediation in the form of a short tutorial after diagnosing student problem. It may include referring the learner back to already mastered material or providing new content.

Alternative is selected according to the need of

the student-and is implemented with prompts (Kaiser, 1972). Some of the most commonly used prompts are given below:

Formal Prompt. This is a part of the response and gives a clue to the learner to provide a correct response.

Thematic Prompt. It uses previous knowledge of learners and guides them to the correct response without indicating the type of response.

Rhyming Prompt. It provides a word that rhymes with the correct response.

Literal Prompt. It evokes a single response in the presence of a number of appropriate stimuli.

Frame-Structured Prompt. It prompts through matching and similarity of ideas.

The use of prompts should be balanced throughout the unit. Over-prompting or under-prompting may cause failure to achieve unit objectives.

Student support is provided during practice sessions or when new material is being taught. It is withdrawn during testing frames for evaluation purposes.

Measuring Student Performance:

Measuring student progress throughout the session is an important part of the CAI design phase. Measurements are taken and recorded to evaluate performance of each individual and to determine the achievement of behavioral objectives and the goals of

the instructional unit. The most commonly gathered statistics include (a) the number of objectives mastered, (b) percentage of course or lesson completed, (c) average response time, (d) average session length, and (e) student comments, if available.

Sometimes, it is important to collect additional information on learners to diagnose other educational problems. It includes determining the validity of the CAI system for gifted and slow learners. In such situations, the individual is monitored throughout the session as to which paths are selected, the difficulties encountered, and how many times help or other tutorial sessions are requested. This statistic also helps to determine the difficulty level of the content, learning style of learners, and the validity of the unit for students with different age, grade, sex, or IQ characteristics.

Student tracking is a difficult task and needs a lot of CPU time. For example, in the TICCIT multi-user CAI system, one processor is dedicated only to track students' performance. However, the use of relational database has provided considerable convenience in its implementation.

Selection of the Language.

Selection of a programming language to code the CAI system is another important task. Several

factors like the availability of the language, appropriateness of the host computer, ease of learning, cost, and utilization rate are considered before making a final choice. At present, several languages are available that have been especially designed for the CAI systems. Such languages are called author languages and provide a set of primitives to write instructional programs. A brief description of some of these important author languages is given below:

COURSEWRITER. It was developed by IBM and is a frame oriented language. It is an off-shoot of TIP (Zinn & Bork, 1978).

TIP. Translator for Interactive Programs is known as the first CAI language and was used on the IBM 650 machine.

TUTOR. It is another frame oriented language with better features than those provided by CAID.

DECAL. It is a CAI language usable only on DEC hardware.

PLAIN. It is a CAI language similar to NATAL and is used in the interactive mode (Wasserman, 1972).

IDF. It is a hardware dependent CAI language and is usable for Hewlett Packard hardware.

PLANIT. Programmed Language for Interactive Teaching is a system independent language and has been implemented on several machines including IBM 360, UNIVAC 1108, CDC6400, PDP-11, VAX, ANGYK-12, and

Q-32, etc. It was developed by System Development Corporation and has enjoyed great popularity.

NATAL. National Author Language is another system independent language developed by Canadians. It has been implemented on DEC10, Honeywell Series 60, and IBM/370 (Westorm, 1977).

PILOT. Programmed Inquiry, Learning, or Teaching is system independent language used on mainframe, mini, and micro-computers (Yob, 1977).

CAN-8. It is a Honeywell system dependent CAI language and was developed at the Ontario Institute for Studies in Education. It is a competing product for NATAL.

SMALLTALK. It is a very user-friendly CAI language with high resolution graphics and simple user interface. It was developed by XEROX.

ASET. Author Systems for Education & Training was produced by UNIVAC and is a system dependent language. It provides computation, graphics, and CAI aids.

Besides author languages, general purpose high level languages have also been used in developing CAI courseware. One such most popular language is BASIC. Most of the CAI courseware available in the market for micro-computer use is written in BASIC. PASCAL is another good candidate for the CAI system due to its data structure and its emphasis on structured

programming. The language C is best suited for the CAI system in UNIX environment. ADA has a good potential for being an authoring language. Presently, it is being used by the U. S. Army. LISP is ideally suited for its powerful expression in knowledge based CAI systems.

Authoring Systems:

The choice between selecting a programming language and an authoring system is based on the programming knowledge of a person. Since most of the teachers who develop CAI courseware are not professional programmers, programs have been developed that take information about curriculum and instructional logic from the teacher and produce a source code to implement the CAI system according to the specifications of the author. These programs are called authoring systems and do not require programming knowledge to operate them. The advantage of the authoring system is that the teacher does not have to learn a programming language nor spend time in writing and debugging the source code. Instead, it provides primitive functions that will implement a logic or choose a strategy with one command. Some authoring systems may even produce the source code in an author language of one's choice. These features have made the authoring systems more portable and popular.

Authoring systems may be grouped into the

following three categories:

Macro-Based. In this category, macros are used to determine screen layout, branching, screen erasure, and other features that would save time and effort for the authors. The systems falling into this cateogry are VAULT and BOOK. The BOOK system allows the teacher to produce programs in general purpose language (Garvey, 1978).

Form-Driven System. In Form-driven system, information is input to describe the course structure, logic, and branching strategy of the instructional unit. The well-known authoring systems that fall in this category are TICCIT, EAASY (Educator's Automated Authoring System), AIS (Advanced Instructional System), CAMIL (Computer Assisted/Managed Instructional Language), and MONIFORMS (Dowsey, 1974, Montgomery & Judd, 1979, Shultz, 1975, & Oliver, 1980).

Prompting System. These authoring sytems allow the development of CAI courseware in interactive mode. Author's responses are used to select content and logic. COURSEMAKER authoring system belongs to this category.

It is not necessary that each authoring system must belong to one of the preceding three categories. A LISP based authoring system, for example, uses both macro-based and prompting approaches (Paloin, 1974).

Authoring systems like CAD can even produce code in more than one author language.

All authoring systems are expected to define or select a particular instructional strategy, specify response data that need to be collected, have capability to layout a lesson just created, control options available to students, document lessons and courses, and translate a course into a specific target language (Kearsley, 1982).

Validation of the Design:

The end of design stage is marked by the completion of several tasks including translation of goals to objectives, development of behavioral objectives, and the selection of instructional branching strategy, host hardware, and author language or authoring systems. The details are also worked out regarding mechanisms to provide student support system, means to monitor student performance, and the kinds of statistics to be collected. All these building blocks shape into a single integrated system called model. The purpose of design validation stage is to review these design decisions independently as well as their impact on other components of the model in terms of the goals CAI system is expected to achieve. The design validation may involve review of (a) software requirement specifications, (b) system performance specifications, (c) system product specifications, (d) project rationale, (e) top level

design, (f) database design, (g) integration plan, (h) configuration management, (i) documentation standards, and (j) future maintenance activity The process of design review is repeated as many times as felt necessary.

Implementation Stage

After the design review, the system design is ready for coding in any author language suitable for the hardware of choice. Sometimes, when the system maintenance or enhancements are to be performed by a non-programmer-like classroom teacher, the authoring system is preferred to author language. The latter provides primitive functions that ease the implementation of CAI design in the language of one's choice.

After coding, various components of the system including system output, system logic, branching strategy, and student support structure are tested individually and in integrated form until time they meet the system product specifications. The statistic collected during the session is also tested for its accuracy.

The overall instructional value of the CAI system is determined during a test run in terms of (1) the amount of learning that took place, (2) the degree of retention of learned material, (3) the

portability of the system, and (4) motivational appeal (measured by drop-out rate of particpants).

In order to keep the system efficient, cost effective, and state of the art throughout its life cycle, provision should be made for future maintenance and enhancements. This is a key factor to marketing. When testing is completed and the system has met all of the design and product requirements, it is ready to be marketed or handed over to the vendor for use.

Advantages

The popularity of CAI systems rests on the advantages they provide over traditional methods. The following list describes how the use of CAI systems may improve instructional processes.

1. CAI has been proved very successful in motivating the individual for learning. The presentation of material in the form of games, puzzles, colorful graphs, and sound keeps the student involved until the end of the session which seldom happens in a traditional classroom situation. Because of the active behavior, the learning process is facilitated (Ames & Carpino, 1977).
2. CAI provides the opportunity to track the individual differences. Students can proceed

through the lesson at their own pace. Gifted students can be presented with more challenging tasks while the poor students can be given more practice lessons.

3. Unlike group teaching in a classroom, CAI makes sure that proper prompting and reinforcement comes immediately and at the right time for each individual.

4. In a simulation mode, the student may explore questions like "What, Why, and How?" which may not be possible in a traditional classroom (Chambers & Sprecher, 1980).

5. It saves time for teachers to develop strategies to ensure quality education.

6. CAI is a very advantageous tool for non-average students. Gifted students satisfy their curiosity by more challenging tasks while those having specific difficulties may take advantage of remedial education.

7. Whether used as a supplement or as a substitute to classroom instruction, CAI is a cost-effective way to impart instruction.

8. CAI provides speeded learning in a friendly environment.

9. The use of graphics in CAI system speeds up the rate of comprehension.

Unresolved Issues

There are many unresolved issues that may be called obstacles in the development and promotion of CAI systems. The following list is not exhaustive but mentions some of the current issues:

1. The implementation of CAI system on microcomputers may require compromise on quality and comprehensiveness due to its limited memory. The segmentation process may solve the memory problem to some extent but it is a very complex procedure and may not be expected from a typical CAI user.

2. Portability of a CAI system across a variety of hardware is still an issue. The developing of an authoring system that is capable of producing source codes in a variety of author or general purpose languages has given some hope.

3. The market is flooded with all kinds of CAI courseware. Some of them might harm instead of providing good. There is a strong need to establish standards to ensure the quality of the courseware before it is marketed.

4. It is important that educational experts develop the instructional unit and computer scientists write software to implement it. The close cooperation between the two groups is essential to the quality of the CAI system.

5. There is no procedure to compare the two CAI

systems objectively. Quantitative measures need to be developed to make comparisons in terms of educational significance, portability, system design, and cost. Such measures will be of great value to potential users.

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